ARMORED MEDICAL RESEARCH LABORATORY

FORT KNOX, KENTUCKY

Final Report

On

PROJECT NO. 35 - DETERMINATION OF THE OPTIMUM METHOD FOR PROTECTION OF TANK CREWS AGAINST CHEMICAL WARFARE AGENTS

Project No. 35

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ARMORED MEDICAL RESEARCH LABORATORY
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EFFECTS UPON TANK CREWS OF SEVERAL METHODS OF PROTECTION AGAINST CHEMICAL WARFARE AGENTS

1. PROJECT: Final Report on Project No. 35 - Determination of the Optimum Method for Protection of Tank Crews Against Chemical Warfare Agents.

a. Authority: Letter, Army Service Forces, Office of The Surgeon General, Washington, D. C., 8th Indorsement, File 700.2-1 (Fort Knox)N, SPMDO, dated 24 April 1944.

b. Purpose: To determine, by field test, the optimum method for the protection of tank crews against Chemical Warfare Agents from the standpoint of factors other than protection against the chemical agents themselves.

2. DISCUSSION:

Previous tests have shown that tank crews can be adequately protected against Chemical Warfare Agents by three methods: (1) individual combat masks, (2) individual ventilated facepieces supplied with purified air from central motor-blower-canister units and (3) collective protection of the entire tank with purified air under positive-pressure ventilation. The first two methods require the crew to wear impregnated clothing at all times; the third method does not require impregnated clothing so long as the tank and protective system are intact.

Accepting the fact that the three methods adequately protect against Chemical Warfare Agents, the relative merits of these methods were determined in a field test carried out for the purpose of determining the heat loads and limitations and advantages of the three methods in terms of physiologic effects upon the crew and upon their ability to discharge their duties. The heat load and the respiratory load appeared to impose the greatest stresses. Impairment of vision, interference with the proper use of visual equipment (particularly fire control) and restriction of movement appeared to constitute the greatest limitations.

A proper evaluation of these loads and limitations required that the tests be conducted in a tropical (hot, humid) climate, since heat and humidity accentuate the loads imposed by gas protective equipment. Camp Polk, Louisiana was chosen for these tests since it was the hottest and most humid region in the United States where tanks were operating. Unfortunately, the weather

at this camp proved to be hot temperate and not sufficiently humid to simulate the tropics. Therefore, the conclusions of this report must be accepted with this reservation and the understanding that in the tropics different effects on the crew may be obtained.

3. CONCLUSIONS:

a. Tank crews can operate and discharge their duties efficiently in buttoned tanks for at least four (4) hours during the hottest part of the day in the hot climate. Longer periods of operation appear possible. This is true whether the crew is unprotected or is equipped with one of the following protective assemblies: (1) combat masks plus impregnated clothing, (2) individual ventilated facepieces and impregnated clothing, (3) collective protector for the entire tank (T23) plus impregnated clothing without the hood and gloves.

b. Equal heat loads, only slightly greater than that of the unprotected control, are imposed by the three protective methods detailed above.

c. Accuracy of fire and sensing were equally good without regard to the type of protection employed.

d. From the standpoint of comfort, total protection with positive pressure ventilation and the ventilated facepiece (with air flow reduced to 3.5 c.f.m.) were preferred to the combat mask. The ventilated facepiece with the prescribed rate of air flow of 6 c.f.m. was strongly disliked, the blast of hot air being barely tolerable.

e. The individual combat mask is considered to be the most acceptable and practical means of protection now available for tank crews. It is not considered the optimum method of protection—its deficiencies, however, can be corrected by development and change.

f. Despite its greater comfort, the individual ventilated facepiece system offers insufficient advantages over the combat mask and is not considered desirable for the following reasons: (1) does not reduce the heat load, (2) does not enable better gunnery when using current fire control equipment, (3) its use in the tank requires the provision of combat masks for use after evacuation of the tank, (4) creates a separate supply, installation, servicing and maintenance problem, (5) it is dependent upon the electrical supply and subject to failure on that account (two such failures occurred during test), (6) if the equipment fails several men rather than one are imperiled, (7) the problem of location of the canister is critical, and has not been solved; it is not clear that properly situated stowage space for this equipment is available, (8) plastic shields scratch easily and are of extremely short life, (9) it has not been established by test that the equipment will provide adequate protection against CWA, when the reduced air flow of 3.5 c.f.m. is used, (10) the hoses restrict movement, cause interference and are easily damaged.

g. Collective protection with positive-pressure ventilation presents a method with many inherent advantages, its further development is desirable.

The sole objection to this method (T23) was the heat in the turret, due to poor distribution of air.

h. The assembly of impregnated clothing has the following disadvantage; the hood is too thick and does not fit well over the crash helmet, the jacket sleeves pull out of the glove wristlets and the jacket bottom out of the trousers.

i. An estimated 50% to 90% of the protective ointment, M5, applied to the neck and face as a substitute for the hood and to the wrist and forearms to protect the jacket-glove juncture, was rubbed off after four (4) hours of operation.

4. RECOMMENDATIONS:

a. That the combat mask and impregnated clothing be considered the most practical method now available for field issue.

b. The development and improvement of combat mask be pursued along following lines:

(1) Reduce the thickness of the attachment tabs of the head harness to the facepiece in order to eliminate localized areas of pressure under the crash helmet.

(2) Rearrange the head harness straps to avoid interference with the newly developed head phones (HS-16 ()/U) for tank crews.

(3) Redesign the eyepieces of the mask to provide for a greater field of vision, give binocular vision at close range, and permit proper use of newer fire control equipment. Reduction of eye relief to a minimum can secure these aims.

(4) Relocate the canister in a position interfering least with other tank equipment and the activities of tank crews.

(5) Reduce canister resistance to the minimum compatible with adequate protection.

c. Further development of collective protection by positive pressure ventilation be pursued.

d. Improve the impregnated clothing assembly: (1) make hood of lighter material and of sufficient size to fit over crash helmet, (2) wristlets of gloves should reach midway to the elbow, (3) fasten rear and front of jacket to trousers.

e. Protective ointment, M5, be considered an inadequate substitute for the impregnated hood and glove wristlets until further tests demonstrate its protective value after prolonged use in closed tanks operating in hot climates.

f. Coordinate all development of protective equipment for use by Armored personnel with the Armored Center.

(NOTE: The conclusions and recommendations set forth above have been concurred in by W. H. Nutter, Colonel, G.S.C., Chief of Staff, Headquarters Armored Center and Lt. Col. G. A. Douglass, Armored Board.)

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3 Incls.
#1 - Appendix
#2 - Tables 1 thru 11
#3 - Charts 1 thru 8

APPENDIX

A. EXPERIMENTAL CONDITIONS AND PROCEDURES

1. Locale and Climate

These tests were carried out at Camp Polk, Louisiana, from 10 July to 10 August 1944. The test area was located between 31° and 32° North Latitude and 93° and 94° West Longitude. The terrain was slightly rolling, moderately covered with second growth pine and largely free of undergrowth. During the test periods, shade was slight and spotty.

The climate was hot temperate. Chart 1 indicates the daily maximum and minimum dry and wet bulb temperatures and relative humidities during the hours of test each day. During the tests, the dry bulb temperature ranged from 88°F. to 103°F. and the relative humidity from 27.5% to 64.5%. Two cool days (D.B. 80°F.) were omitted from this study and are not considered here. The averages of the daily maximum dry and wet bulb temperatures were 96.3°F. and 77.8°F. respectively. Diurnal and daily variations in wet bulb temperature were small; accordingly, the relative humidity changed indirectly with the dry bulb temperature. Rain was infrequent and did not occur during the test periods utilized in this report. Since the test periods extended from 1100 hours to 1600 hours, the temperature during a test was not uniform but slowly rising throughout.

2. Subjects

Sixteen enlisted men and four officers comprised four tank crews and served as experimental subjects. One officer occupied the loader's position in each tank. In addition to being a subject, he was the observer for his tank. The enlisted men were healthy, physically fit and had been training at Camp Polk at least since early spring. The officers were older and less fit than the enlisted men. The ages of the subjects ranged from 19 to 36 years, but only one enlisted man was over 21 years. The subjects lived in barracks on the post and subsisted on field ration A eaten at 0600, 1000 and 1730 hours.

3. Protective Equipment

Four tanks were equipped as follows: one (M4A3) with individual M5-11-7 combat masks with M11 canister (formerly E6-3-7 assault masks), another (M4A3) with the individual ventilated facepiece system (Protector, facepiece, E21R1), the third (electric drive tank, T23) with collective protection (canister E8) for the entire tank and positive pressure ventilation and the fourth tank (M4A3) served as a control. Initially, the air flow to each ventilated facepiece was approximately 6 c.f.m. This air blast proved to be intolerably hot and the rate of flow was reduced to 3.5 c.f.m. per facepiece for the final tests. The T23 tank was sealed and supplied with 275 c.f.m. of purified air, producing a positive pressure of three-fourths inch. The four

tanks were operated simultaneously each day with the crews rotating through them according to a randomized Latin Square. Each crew operated each tank for a day and at the end of four (4) days had experienced each of the three types of protection and the control.. Regulation fatigue clothing (shorts, socks, 2 piece coverall, shoes and leggings) was worn in the control tank. In the three protected tanks, the men wore the following impregnated (CC-2) clothing: shorts, socks, trousers, jacket, hood and gloves and non-impregnated shoes and leggings. The M5 protective ointment was substituted for the hood in special studies.

4. Work

The test period consisted of 4 hours (between 1100 and 1600 hours) of buttoned-up driving over a 3.5 mile standardized, moderately rough trail, winding among the trees. The tanks followed each other around the course in a staggered fashion, averaged 10 miles per hour and completed a circuit in 20 to 25 (usually 23) minutes. Two circuits were made each hour (fast run). During the remaining 10 to 15 minutes, the tank was stationary and data was taken. In some tests, one circuit was made per hour with the tank stationary for the remaining 35 to 40 minutes, (slow run). During all stationary periods, the engine was idling. Only the driver worked during the test period, the remaining 4 men merely rode. Each man entered the tank with 3 canteens of water (2,700 c.c.) from which he was permitted to drink during the hourly halts for data taking. At these times, combat masks, ventilated facepieces and hoods were removed for 5-8 minutes.

5. Data

a. Weather

During the test period, the dry and wet bulb temperatures, wind velocity and direction, and condition of the sky (sunlight) were recorded every half hour. During the other hours of daylight, the same determinations were made at hourly intervals.

b. Tank

Hourly readings of the dry and wet bulb temperatures were made in the bow (bog) and turret (gunner) as soon as the tank halted. At the same time, the temperatures of the final drive and of three locations on the hull (bow top, turret top, turret side) of two representative tanks were measured by thermocouples. During slow runs, temperature readings were made on halting and at the end of resting period.

c. Subjects

The oral temperature, the rectal temperature, and the weight (within 5 grams) of all crew members were determined before entering and after dismounting the tanks. At these times, the men were naked and their urinary bladders empty. During the hourly halts of the tank, the heart rates and oral temperatures were determined. Continuous notes were made of the appearance of the men, their reactions and complaints and the proficiency of the driving.

Both the water drunk during the four hour period and the urine excreted were measured.

6. Typical Daily Schedule

0800 hours	Tanks arrive at test area with crews.
0800 to 1000 hours	Preparation of tanks and equipment for test run. Tanks "sitting" in sun, hatches open.
1000 to 1030 hours	Lunch
1030, 1045, 1100, 1115 hours	The 4 crews, in order and successively, have initial data taken, dress in designated clothing and equipment.
1045, 1100, 1115, 1130 hours	The 4 crews, in order and successively, enter designated tanks and button up, motor idling.
1100, 1115, 1130, 1145 hours	The 4 crews, in order and successively, begin test runs over course, buttoned-up.
1500, 1515, 1530, 1545 hours	The 4 crews, in order and successively, dismount tanks and have final data taken.
1545 to 1645 hours	Collection and storing of test equipment, policing of area.
1700 hours	Test area vacated.

B. PHYSIOLOGIC CHANGES

1. Thermal Load

The thermal loads imposed during the test period on the bow and turret crews of a standard M4A3 tank and of an experimental (T23) electric drive tank are plotted in Charts 2 and 3 respectively. These charts also indicate the relationship of the air and hull temperatures of these tanks to the ambient air temperature. The plotted day was one of the hotter ones but the data is representative. Both tanks operated simultaneously. In the M4A3 tanks, the bow air temperature generally exceeded the ambient temperature by 20°F. for the dry bulb and 11°F. for the wet bulb (Table 1). The turret air increased less in temperature, 7°F. for the dry bulb temperature and 5°F. for the wet bulb temperature (Table 1). In the T23 tank, the bow air temperature exceeded the ambient temperature by 9°F. for the dry bulb and 6°F. for the wet bulb. Corres-

ponding increases in the turret air were 6°F. D.B. and 9°F. W.B. (Table 1).

2. Fast and Slow Runs

In cruising M4A3 tanks, the air flow varies from 1200 to 1500 c.f.m. When stationary with engine idling the flow is only 300-400 c.f.m. Since the internal environment of the tank might deteriorate badly at the lower air flows, it became necessary to determine whether there were significant differences in the tank environment and in the physiologic changes in the crew when the tank was largely on the move (fast run) and when largely stationary with engine idling (slow run). The relationship of the environment of a M4A3 tank to the ambient temperatures during a day of slow running is plotted in Chart 4 which should be compared with Chart 2, a plot of similar data during a fast run. A similar comparison is obtainable from Table 1. The combined data indicates the essential similarity of the tank environments during both types of runs. Table 2 indicates that the sweating rates, rectal temperatures and heart rates were somewhat higher during the slow than fast runs. The changes during both types of runs are still of the same order of magnitude and within the same physiologic range. The differences are at best small and not of practical importance. This permits treatment of the data from fast and slow runs without differentiation, a course to be pursued henceforth. All tanks operated either fast or slow on the same day.

Since the ventilation rate of the T23 tank is fixed by the blower-canister system and is independent of the movement of the tank, the data on this tank will not be separated into fast and slow runs. Chart 5 (slow run) and Chart 3 (fast run), together with Table 1, indicate the essential similarity of the environment within this tank during both types of operation.

3. Effect on Sweating, Rectal Temperature and Heart Rate

Table 3 details the physiologic changes (sweating rate, rectal temperature and heart rate) at the end of 4 hours of closed operation in three tank crews, which rotated through the three methods of protection and the control. The data on crew 3 have been excluded. This crew failed to complete 4 hours of operation with the facepiece system (mechanical failure) and did not wear the hood and gloves in the totally protected (T23) tank.

In the M4A3 tanks, the physiologic changes are greatest in the bow crew (particularly the driver) and considerably smaller in the turret crew. This was true for both the unprotected crew in regulation fatigue clothing and for the protected crew whether equipped with combat masks or ventilated facepieces. The bow men lose twice as much sweat (400 c.c. to 500 c.c./hour more) as the turret men, have rectal temperatures that are 1°F. to 1.5°F. higher, and pulse rates that are 25 to 30 beats/min. faster (Table 3). In the totally protected, positive pressure ventilated, tank (T23) the situation is reversed, greater changes occur in the turret crew (particularly in the loader and commander) than in the bow crew. The differences, however, are not so great as in the M4A3 tanks. The turret crew loses about one-third again as much sweat (200 c.c./hour more) as the bow crew, attains rectal temperatures that are 0.3°F. higher and pulse rates that are faster by 20 beats/minute.

On the assumption that the physiologic load can be evaluated by the changes in sweating rate, rectal temperature and heart rate, Table 3 and Charts 6, 7, and 8 indicate the loads imposed on tank crews by the various protective methods. It is at once apparent that the major load is imposed by the buttoned tank and that the various types of protective equipment impose only slight additional loads, which in themselves are not sufficient to produce changes significantly beyond the order of magnitude of the control. In the M4A3 tanks, this is exemplified by the driver, who withstands the greatest load (both thermal and work) and sustains the greatest changes. With protective equipment, his sweating rate averages 1 litre/hour, only 150 c.c. to 200 c.c./hour more than in the control tank without protection; his rectal temperature ranges between 101°F. and 101.5°F., only 0.5°F. to 0.75°F. higher than in the control and his heart rate of 110/min. to 120/min. exceed his control rate by only 10 to 20 beats/min. In the other crew members, the loads were considerably less and physiologic disturbances more mild.

In the totally protected (T23) tank, the changes were of the same order of magnitude as in the M4A3 tanks with protection, except that the greatest load fell on the turret crew with the loader and commander sustaining physiologic changes similar to those of the driver in the M4A3 tanks Table 3, Charts 6, 7, 8).

The order of magnitude of the physiologic changes indicates that the loads imposed on the crew are moderately severe (driver in M4A3, loader and commander in T23), but still below the limits of tolerance. There were indications that such limits of tolerance were at times closely approached. On four occasions during the month of operation, men (all drivers) were forced by disability to leave their tanks before the end of 4 hours. On two of these occasions, the failure to finish was attributed to an insufficient water intake. On several other occasions, men forced themselves to finish the scheduled 4 hours of test in spite of severe symptoms and their obviously poor and inefficient condition.

Employing the average of the sweating rates, rectal temperatures and heart rates for the five men of the crew as an index of the overall load of the protective systems, the totally protected tank (T23) with a ventilation rate of 275 c.f.m. imposes a slightly greater load than the individual combat mask or the ventilated facepiece system (Table 3). The last two methods impose equal loads. The differences between the three systems are not sufficiently great to permit a preference of one method over the other two on the basis of the physiologic changes induced. In the climate of this study, therefore, the preference for one method over the others would have to be decided on some basis other than the physiologic load.

C. OPERATIONAL LOAD

The evaluation of the operational loads imposed by the protective equipment was based on observations of driving and of target firing.

1. Driving.

The officer observer in each tank quickly learned to appraise the driving ability and characteristics of his driver. In spite of the subjectiveness of this evaluation, it is significant that on each occasion that drivers reached, or came close to, their limits of tolerance, a change in driving was noted by the officer observer. The driving became more rough and "slap-dash" with a tendency to take the bumps "on the fly" and to hit trees.

Usually the driving was excellent, carefully and well done. No change was noted when the drivers were subjected to the three types of protective equipment.

2. Firing

No ammunition was available for the 76mm gun of the totally protected tank (T23). Therefore, the tests were limited to firing the 75 mm gun of the M4A3 tanks by crews equipped in rotation with combat masks, ventilated facepieces and no protection.

a. Procedure

Three tanks fired on each of three days. During the firing tests regular loaders replaced the officer observers heretofore in the loader's position. In one tank, the crew was equipped with combat masks and impregnated clothing; in another with individual ventilated facepieces and impregnated clothing; in the third no protection and regulation fatigue clothing. The crews rotated from one tank to another daily until each crew had fired under each of the three above listed situations.

The crews donned their designated equipment and entered the tanks at approximately 1130 hours, immediately buttoned completely, and thereafter remained completely buttoned until the end of the firing program ($3\frac{1}{2}$ to 4 hours in all). After entering the tanks, the crews drove, completely buttoned, to the firing range. This required $1\frac{1}{2}$ to 2 hours. At the range, high explosive ammunition (75mm, HE, M48) fused on delay was fired at standard HE targets. Fifteen rounds in three bursts of 5 rounds per burst were fired at a far target (approximately 1,200 yards) and ten rounds in two bursts of 5 rounds per burst at a near target (approximately 800 yards). The tanks fired in rotation, one burst at a time, a tank beginning fire after another had ceased. Following each burst of 5 rounds, each tank elevated its gun and moved back 100 yards from the firing line and behind the crest of a hill. Here it waited with idling engine until signalled to advance to the firing line and deliver another burst of 5 rounds. The far and near targets were engaged alternately. Once on each day, each tank fired a burst at the far target and immediately thereafter a burst at the near target before moving back from the firing line. On all other occasions only one burst was fired on each trip to the firing line.

In the observation tower, observers equipped with binoculars estimated the distance from the target of the burst of each round and recorded its location on a grid. The bow gunner of each crew (listening over the interphone) recorded the sensings and firing orders of his commander for each round. From a comparison of the two records, the correctness of the sensings and the degree of interference by the protective equipment was determined. In this study, the accuracy of sensings is limited to the gross classification of over and short.

At the conclusion of the firing, the blast crater of each round was located and its distance from the target measured and recorded. Since deflection from the gun-target line was minimal, only the distances in front and behind the target were measured. From this data, the mean of the distances of the bursts from the target and the dispersion of the individual blasts about the mean were calculated.

b. Sensing

In this analysis, a sensing was called wrong only when it was entirely incorrect, e.g., a short or over called target, a short called over, or vice versa. No attempt was made to determine the precise accuracy of the sensing, e.g., an over called 200 yards over was considered correct even though it was actually only 50 yards over.

Table 4 indicates the accuracy (rather the inaccuracy) of the sensings of the three commanders on the three days of test. Of the three crews, crew A and commander A tried most consistently on all days making their data the most reliable. Several facts emerge from the Table. The percentage of grossly wrong sensings is high, both for crews with and without the protective equipment. In buttoned tanks, sensing inaccuracy is of the same magnitude whether crews wear combat masks or ventilated facepieces or no protective equipment (see Crew A, Table 4). An appreciable learning curve is present for each crew, but is indicated best by Crew A (40% wrong first day, 24% second day, 24% third day). Since the same range was used on each day, the true improvement in sensing ability from a buttoned tank is not indicated by these data. A new range each day would be required to determine this point.

c. Accuracy of Fire

The accuracy of the fire for both targets was determined in two ways: (1) determination of the mean of the distances of the blasts from the target and the dispersion of blasts about the mean in terms of the standard deviation (Table 5); (2) determination of the number of effective rounds; i.e., rounds bursting within the effective bursting radius of the ammunition for a horizontal target (20 yards short and 5 yards over)(Table 6). The scores for the near targets will be discounted. These targets were badly placed in a hollow behind an upward roll in the terrain. Rounds going slightly over the target became far over and attempts to shorten the range yielded far shorts on the crest of the roll.

An analysis of both scoring methods (Tables 5 and 6) permits the following conclusions: (1) fire from a completely buttoned tank can be reasonably accurate; (2) fire from a completely buttoned tank is of the same degree of accuracy whether crews wear combat masks or ventilated facepieces or use no protective equipment; (3) there is a decided learning curve in the laying of accurate fire from a buttoned tank (since the firing was on the same range each day, the true extent of this learning can not be indicated by this data). Again crew A gave the most consistent and reliable data.

Since fixed white targets were used for the firing tests, no attempt was made to determine the effect of the protective equipment on the commander's ability to spot and recognize more natural targets. Neither the physiologic nor operational load permitted a preference of one protective method over the other. There remains then an evaluation of the comfort-discomfort load of each system.

D. COMFORT-DISCOMFORT LOAD

1. Questionnaire

At the end of the test program and after they had become accustomed to the equipment through repeated use, each man was personally and individually questioned regarding his preference for the protective methods and his complaints for each item of the assemblies. The results of this questionnaire (Table 7) indicated that the men were equally divided in their first choice between the ventilated facepiece system (only when air flow to each facepiece is reduced to 3.5 c.f.m.) and the totally protected tank (T23) with positive pressure ventilation (when hood and gloves of impregnated assembly are not worn). The combat mask was universally considered the least comfortable, chiefly due to the resistance to respiration. At the same time, it was considered not to render the operation of the tank much more difficult, except for the gunners. The canister on the left cheek markedly interfered with their use of the telescopic sight. Table 8 is a detailed breakdown of this expression of preference according to position in the tank and the strength of the choice.

2. Complaints

Table 9 details the complaints registered by the men against the protective equipment and requires very little comment. Although the complaints against the combat mask were numerous, they were usually not critical and most crew members agreed that interference with operation was not great. (Note: men frequently fell asleep while wearing the combat mask). The complaints against the ventilated facepiece system in this table are for the revised arrangement with the air flow to each facepiece reduced to 3.5 c.f.m. and the canister-motor-blower units placed in the coolest locations possible. When submitted for test each facepiece received 6 c.f.m. of air and the blast of this amount of hot air was extremely disagreeable. Under such conditions, the crews preferred the combat mask to the ventilated facepiece system. The complaints against the totally protected positive pressure tank were entirely by the loader and commander. The other three crew members, located near the canister outlet, found this system very pleasant and desirable. Wearing the full impregnated assembly

rendered the loader and commander incapable of functioning and the tank inoperable. Removing the hood and gloves (but having them at hand) rendered the load on the loader and commander bearable and the tank operable.

3. Modification of Equipment

During the testing period, the equipment of each method of protection was modified from time to time to give greater comfort. There finally emerged a "final" form for each method. The "final" combat mask system consisted of a fitted combat mask (several men required special facepieces) with the inner nose piece removed, plus the full assembly of impregnated clothing. In the "final" ventilated facepiece system, the air flow to each facepiece was reduced to 3.5 c.f.m. and the crew wore the full assembly of impregnated clothing. In the totally protected tank (T23), the crew wore only the impregnated clothing, but with the gloves in their pockets and with the hoods thrown off the head and over the back (clothing in readiness for evacuation). These three "final" methods were compared in a simultaneous run on a single day. The physiologic effects induced in the three crews are indicated in Table 10 and these should be compared with similar data in Table 3 (before institution of comfort changes). It is evident that although the comfort of the crew was increased, the physiologic disturbances remained of the same order of magnitude.

It was later suggested that comfort in the turret of the totally protected tank (T23) might be increased by better circulation of the air in the turret. A 200 c.f.m. fan was placed just above the canister and directed the air in 2 streams toward the turret. This arrangement increased markedly the comfort of the crew but produced only a slight reduction in the induced physiologic disturbances (Table 11).

4. Faults of Items of Protective Equipment

Often synonymous with the above detailed complaints but not necessarily, nor always, identical are the following observed faults which should be corrected.

a. Combat Mask. (1) The facepiece and harness do not fit comfortably under the crash helmet. Elevated attachment tabs of head harness to facepiece cause focal pressure points. (2) Improper fit across forehead and under chin--greater variety of sizes. (3) Canister - too heavy causing neck fatigue. - Canister on left cheek interferes with gunner's use of telescopic sight. - Lateral position endangers seal of mask on face. (4) Inner nose cup too narrow, occludes nose and interferes with respiration. (5) Eyepieces too widely separated, limiting central visual field and causing monocular vision at close range. (6) Metal clasps on adjusting straps cut into the back of the ears.

b. Ventilated Facepiece System. (1) Flow of air to facepieces too hot. (2) Air supply hoses in the way, too soft, collapse readily on external pressure, twist and kink on themselves. (3) Plastic shields much too soft,

scratch easily and badly becoming practically non transparent in several (3-4) days. (4) Facepiece does not fit well under crash helmet, all leakage over forehead blocked. (5) Chin leakage valves tend to become occluded by the hood. (6) Difficulties in proper placing of canister-motor-blower unit as to stowage and relatively cool location, particularly bow unit. (7) Drain on power resources of the tank.

c. Totally Protected Tank (T23). (1) Difficulty in proper placement of the canister and blower leading to (a) excessive heat in turret; (b) inadequate air circulation in turret; (c) stowage difficulties.

d. Impregnated Clothing Assembly. (1) Hood. (a) Too thick and too heavy. (b) Not designed to fit over crash helmet and around canister of combat mask. (c) Buttons around neck not properly placed. When fully buttoned, hood chokes around neck. (d) Possible break in protection between hood and jacket where interphone and microphone cords pass. (2) Gloves. Wristlets too short permitting sleeves of jacket to pull out of glove. (3) Jacket. Jacket tends to pull out of trousers.

E. PROTECTIVE OINTMENT M5

It has been suggested that the M5 protective ointment can replace the hood when an ample layer of the ointment is applied over skin areas usually covered by the hood. Similarly, its use on the wrists and lower forearms is suggested to protect an area often made vulnerable by the pulling of the jacket sleeve out of the glove.

Protective ointment M5 was applied to these skin areas of two tank crews wearing combat masks and the impregnated assembly except for the hood. After 4 hours of operation in closed tanks, 50% to 90% of the ointment had been rubbed off the different areas of the skin, most of it into the clothing. Large areas, particularly of the neck and wrists were completely free of ointment with only small flecks remaining on the skin. Crew members subjected to the greatest movement (driver, loader) rubbed most of the ointment from the skin. One loader sustained chafing of the skin of the side of both jaws leading to denudation of skin from these areas. It was estimated that the ointment remained on the skin in protective quantities for not more than one hour. Unless some means is discovered to prevent the ointment from being rubbed off or to reapply it frequently, the ointment does not appear to be a substitute for any item of protective clothing.

FINAL EVALUATION

In the climate of this study the combat mask with impregnated clothing proved to be a simple and operable method of protection, which with further improvement can become a nearly optimum method. Such development should be

energetically pursued. Certainly the simplicity of the method, its personal nature and its lack of demands on stowage, power, and additional equipment make it a very desirable method. Although placed last in the preference ratings, the combat mask cannot be considered to impose a high discomfort load. Men frequently fell asleep in the tank while wearing the mask.

The ventilated facepiece system and totally protected tank (T23) offered advantages over the combat mask solely from the standpoint of comfort. The chief objection to these methods is not in the methods themselves but in the ability of the men to do so well with the combat mask. This coupled with the consideration that all crew members will require combat masks and impregnated clothing for evacuation of tanks make it difficult to propose one of the other methods, in which one must take into consideration: (a) installation of new equipment, (b) supply of the equipment, (c) power requirement, (d) servicing of the equipment, (e) maintenance of equipment with replacement parts, (f) possible failure of operation of equipment through negligence of one man or through mechanical failure endangers several men, not one; (g) the problem of stowage is critical and has not yet been solved, nor is it decided that properly situated stowage space is available; (h) availability of non scratching plastic shields for the facepieces is not yet assured, (i) Adequate protection against CWA by an air flow of 3.5 c.f.m. per facepiece has yet to be established.

Incl. #1

TABLE I

INCREASE IN DRY AND WET BULB TEMPERATURES OF
BOW AND TURRET AIR OVER OUTSIDE AIR TEMPERATURE

(Standard M4A3 Tank and a Totally Protected Experimental Tank (T23)

Day	Ambient Air Temp.		MAXIMUM INCREASE IN TEMPERATURE OVER AMBIENT (°F.)							
			M4A3*				T23†			
			Turret		Bow		Turret		Bow	
	D.B.	W.B.	D.B.	W.B.	D.B.	W.B.	D.B.	W.B.	D.B.	W.B.
			FAST RUNS							
10	99.5	74.5	6.5	5.5	19.5	8.5	5.0	9.0	8.0	6.0
11	100	76	6.7	5.7	21.3	12.0	5.0	9.5	10.0	5.5
13	93.5	77.5	7.5	6.5	19.7	9.7	2.5	8.0	6.5	6.0
24	97.0	78.5	8.0	5.5	23.7	12.2	7.0	8.5	11.0	7.0
32	93.0	76.0	7.0	4.0	17.0	12.0	9.0	9.0	9.0	6.0
Avg.	96.6	76.5	7.1	5.4	20.2	10.9	5.7	8.8	8.9	6.1
			SLOW RUNS							
12	99.0	77	9.3	6.3	22.7	11.0	11.0	9.0	19.0	5.5
17	92.5	76	9.8	5.5	14.2	10.3	8.5	8.0	10.5	5.0
18	94.0	78	13.7	8.7	21.4	10.0	10.0	11.0	13.0	9.0
Avg.	95.2	77	9.3	6.8	19.4	10.4	9.8	9.3	14.2	6.5

*Average of 3 tanks per day (one tank on day 32, two tanks on day 10)

†One tank only.

TABLE 2

COMPARISON OF PHYSIOLOGICAL CHANGES
DURING FOUR HOUR FAST AND SLOW TANK OPERATION

(Standard M4A3 Tank, Crew Equipped with Combat
Masks and Full Impregnated Clothing Assembly)

CREW POSITION		SWEAT LOSS/HR.		FINAL RECTAL TEMP.		FINAL PULSE	
	Crew Member	Fast	Slow	Fast	Slow	Fast	Slow
Commander	3 4	360 365	602 377	99.4 99.2	99.8 99.8	73 66	75 75
Gunner	3 4	469 400	489 460	99.4 99.2	99.7 99.2	57 81	72 84
Loader	3 4	302 459	432 450	100.3 100.0	100.5 100.3	102 99	87 96
Bog	3 4	759 463	902 513	100.8 99.8	101.3 100.6	76 99	120 105
Driver*	3 - 3' 4 - 4'	1065 698	1125 1010	- 101.6	101.9 101.6	99 144	96 144
Average		534	636	100.0	100.5	90	95

*Different drivers on the two days.

WEATHER DATA

During the Four (4) Hours of Test

Day of Test	Temperature (°F.)						Relative Humidity (%)		
	Dry Bulb			Wet Bulb					
	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.
6	95	97	96.1	73	75	73.9	32	34.5	33.6
7	93	99	95.9	74	76	75.1	33.5	40	37.7

Incl. #2

TABLE 3

COMPARISON OF SWEAT LOSSES, RECTAL TEMPERATURES AND PULSE RATES IN THREE (3) TANK CREWS EQUIPPED WITH DIFFERENT PROTECTIVE DEVICES

(Four Hours of Buttoned Operation, Crews in Impregnated Clothing, except for Control)

CREW POSITION		SWEAT LOSS (gms/hr.)				FINAL RECTAL TEMP. (°F.)				FINAL PULSE RATE (beats/min.)			
	Crew Number	Control	Combat Mask	Ventilated Facepiece*	T23	Control	Combat Mask	Ventilated Facepiece*	T23	Control	Combat Mask	Ventilated Facepiece*	T23
Comdr.	1	367	319	431	1000	99.2	98.9	100.1	101.3	72	81	105	117
	2	359	464	363	649	98.6	99.6	99.1	99.6	64	88	60	92
	4	281	377	388	731	99.4	99.0	99.2	101.0	63	60	66	75
Avg.		336	387	394	793	99.1	99.2	99.5	100.6	66	76	77	95
Gunner	1	335	404	488	769	99.0	98.8	99.5	100.2	72	75	84	96
	2	333	399	350	445	98.8	99.4	98.9	99.6	72	76	68	80
	4	267	438	387	732	99.0	98.8	99.2	98.8	69	75	81	99
Avg.		312	414	408	649	98.9	99.0	99.2	99.5	71	75	78	92
Loader	1	383	376	578	864	99.2	99.0	100.1	100.6	72	75	93	108
	2	395	547	413	1085	99.4	99.6	99.4	100.3	76	88	72	116
	4	298	470	491	932	99.6	100.2	100.4	101.0	87	102	96	132
Avg.		359	464	494	960	99.4	99.6	100.0	100.6	78	88	87	119
Bog	1	666	563	790	618	99.5	99.6	101.0	99.6	93	84	99	93
	2	714	1215	662	608	100.6	101.8	100.2	100.0	108	124	104	60
	4	480	837	696	706	100.1	100.3	101.0	100.0	81	99	108	78
Avg.		620	872	716	644	100.1	100.6	100.7	99.9	94	102	104	77
Driver	1	693	912	975	612	99.8	99.9	101.4	100.0	84	93	102	75
	2	1190	1139	1195	744	101.6	101.0	100.8	100.2	136	120	124	108
	4	693	905	858	566	99.6	101.6	101.2	99.9	93	111	111	84
Avg.		859	985	1009	641	100.3	100.8	101.1	100.0	104	108	112	89

SUMMARY

Bow Men	739	929	863	642	100.2	100.7	100.9	100.0	99	105	108	83
Turret Men	335	422	432	801	99.1	99.3	99.5	100.3	72	80	81	102
Entire Crew	497	624	604	737	99.6	99.8	100.1	100.1	83	90	92	94

*Flow to Ventilated Facepieces, 6 c.f.m

Incl. #2

TABLE 3 (Cont'd.)

WEATHER DATA

During the Four (4) Hours of Test

Day Of Test	TEMPERATURE (°F.)						RELATIVE HUMIDITY (%)		
	Dry Bulb			Wet Bulb					
	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.
10	96	100	98.4	73.5	77	74.7	27.5	38	31.7
11	95	100	98.4	75	77.5	76.1	29	45	35.2
12	93	102	97.9	76.5	78.5	77.4	32	47	39.6
13	90	97	93.6	75.5	80	78.2	43.5	59	50.4

SCHEMA OF TEST

Day of Test	CREW 1	CREW 2	CREW 3	TYPE OF RUN
10	Control	T23	Combat Mask	Fast
11	T23	Control	Ventilated Facepiece	Fast
12	Ventilated Facepiece	Combat Mask	T23	Slow
13	Combat Mask	Ventilated Facepiece	Control	Fast

TABLE 4

MAGNITUDE OF ERROR IN THE GROSS SENSING OF FIRE FROM BUTTONED TANKS. CREWS WITH AND WITHOUT PROTECTIVE EQUIPMENT

No Protection, Fatigue Clothing			Combat Mask, Impregnated Clothing			Ventilated Facepiece, Impregnated Clothing		
Day	Crew	% Wrong*	Day	Crew	% Wrong*	Day	Crew	% Wrong*
19	A	40	19	B	48	19	C	65
20	C	40	20	A	24	20	B	24
21	B	60	21	C	--	21	A	24

*Percent of total rounds incorrectly sensed. Includes both far and near target.

Incl. #2

TABLE 5

ACCURACY OF FIRE FROM BUTTONED TANKS
BY CREWS WITH AND WITHOUT PROTECTIVE EQUIPMENT

Protection	Day	Crew	FAR TARGET		NEAR TARGET	
			Mean of Bursts* Yards	Standard Deviation About Mean Yards	Mean of Bursts* Yards	Standard Deviation About Mean Yards
None. Fatigue Clothing	19	A	+ 3 yds.	33.4	-131	113
	20	C	- 4.4	37.6	- 11.0	50
	21	B	+10.7	27.3	+ 10.0	24.5
		Avg.	+ 3.1		- 33	
Combat Mask. Full Impregnated Clothing	19	B	+10	64	- 3	71
	20	A	- 9	35	- 37	96
	21	C	0	16.7	33.1	40.4
		Avg.	+ 0.3		- 2.3	
Ventilated Face-piece. Full impregnated clothing	19	C	+ 8	88	- 14	19
	20	B	+65	137	- 29	83
	21	A	0	16.7	- 33.1	40.4
		Avg.	+24		- 25.4	

Far target, 15 rounds; near target, 10 rounds.

*Mean of the distances of the bursts from the target.

TABLE 6

EFFECTIVENESS OF FIRE (H.E.) FROM BUTTONED TANKS BY CREWS WITH AND WITHOUT PROTECTIVE EQUIPMENT AGAINST CHEMICAL WARFARE AGENTS

(Number of Rounds Bursting Within Effective Range, Horizontal Target.)

			FAR TARGET*		NEAR TARGET*	
Protective Equipment	Day	Crew	Effective Rounds Number	Effective Rounds %	Effective Rounds Number	Effective Rounds %
None. Fatigue Clothing	19	A	7	47	0≠	0
	20	C	2	13	4	40
	21	B	4	27	3	30
	Average		4	29	2	23
Combat Mask Impregnated Clothing	19	B	2	13	2	20
	20	A	3	20	2	20
	21	C	11	73	3	30
	Average		5	35	2	23
Ventilated Facepiece Impregnated Clothing	19	C	4	27	2	20
	20	B	4	27	2	20
	21	A	8	53	7	70
	Average		5	36	4	37

*Rounds fired per crew per day - far target (1,200 yards) - 15 rounds
near target (800 yards) - 10 rounds

≠Target in poor site.

Incl. #2

TABLE 7

TYPE OF PROTECTION CONSIDERED FIRST CHOICE
BY TANK CREWS ON THE BASIS OF COMFORT

Type of Protection	Number of Men		TOTAL
	Strong Preference	Mild Preference	
Combat Mask, full impregnated assembly	0	1	1
Ventilated Facepiece System*(3.5 c.f.m.), full impregnated assembly	6	4	10
Totally protected, positive pressure tank (T23), impregnated assembly without gloves or hood.	6	3	9

Second choice of Men who considered T23 first choice:

Ventilated Facepiece System	7
Combat Mask	2

*With an air flow of 6 c.f.m. to each facepiece, the ventilated facepiece system was considered intolerable by most men.

Incl. #2

TABLE 8

PREFERENCE FOR TYPES OF PROTECTIVE EQUIPMENT
ON THE BASIS OF COMFORT BY CREW POSITION

Type of Protection		NUMBER OF MEN					
		First Choice		Second Choice		Third Choice	
		Strong	Mild	Strong	Mild	Strong	Mild
Commanders	Combat Mask				1		3
	Ventilated Facepiece*	2	1	1			
	Total Protection	1		2		1	
Gunners	Combat Mask				1		3
	Ventilated Facepiece*		1		2		1
	Total Protection	1	2		1		
Loaders	Combat Mask		1		2		1
	Ventilated Facepiece*	1	2		1		
	Total Protection				1	3	
Drivers	Combat Mask				1		3
	Ventilated Facepiece*	2			1		1
	Total Protection	1	1		2		
Bow Gunners	Combat Mask						4
	Ventilated Facepiece*	1		1	2		
	Total Protection	3			1		

Combat Mask = combat mask, plus full impregnated assembly.

Ventilated Facepiece = collective protector with individual ventilated facepieces (flow reduced to 3.5 c.f.m.) plus full impregnated assembly.

Total Protection = totally protected tank (T23) with positive-pressure ventilation (275 c.f.m.) plus impregnated assembly without hood or gloves.

*Ventilated Facepiece System with 6 c.f.m. per facepiece was strongly disliked.

TABLE 9

COMPLAINTS EXPRESSED AGAINST THE PROTECTIVE EQUIPMENT

I. COMBAT MASK
   a. Discomfort
      1. Headache or distress from pressure on temple
      2. Pressure on forehead due to pressure of crash helmet on projections of mask.
      3. Discomfort from head harness pressure
      4. Pressure of eyepieces
      5. Uncomfortable chin pressure
      6. Breathing difficulty
      7. Neck fatigue
      8. Irritation of skin
      9. Annoyance from perspiration
      10. Obstruction to breathing by inner nosepiece

   b. Limitation of Vision
      1. Inadequate field of vision
      2. Eyepieces too far apart (central blind spot)
      3. Fogging of lens
      4. Scratching of lens

   c. Interference with Operation
      1. Canister on left cheek interferes with gunner's use of telescopic sight
      2. One driver felt mask "cramped" his driving ability.

II. VENTILATED FACEPIECES AT REDUCED FLOW (3.5 c.f.m.)
   a. Discomfort
      1. Excessive warming of face
      2. Irritation of eyes
      3. Drying of nose or throat
      4. Induction of drowsiness
      5. Poor fit under crash helmet

   b. Interference with Operation
      1. Reduced vision (scratching of eye shields)
      2. Hose-pieces in way

III. TOTALLY PROTECTED, POSITIVE-PRESSURE VENTILATION (T23)
   (Men not wearing hood or gloves)
   a. Discomfort
      1. Hot and stuffy
      2. Nausea

TABLE 10

COMPARISON OF THE THREE MODIFIED (FINAL) ASSEMBLIES OF GAS PROTECTIVE EQUIPMENT FROM STANDPOINT OF THE PHYSIOLOGIC CHANGES INDUCED IN THE CREW

Position	SWEAT LOSS (gms/hr.)			FINAL RECTAL TEMP. (°F)			FINAL PULSE RATE (beats/min.)		
	Combat Mask	Ventilated Facepiece	T23	Combat Mask	Ventilated Facepiece	T23	Combat Mask	Ventilated Facepiece	T23
Commander	367	395	738	99.4	99.7	100.2	72	60	72
Gunner	415	367	707	98.9	99.6	99.0	81	84	78
Loader	364	339	820	99.2	100.1	101.0	78	96	119
Bog	827	756	471	100.2	100.4	99.8	87	96	81
Driver	904	1433	464	100.4	101.2	100.0	96	120	84
Average	575	658	640	99.6	100.2	100.0	83	91	87

WEATHER DATA
During Four (4) Hours of Test

AIR TEMPERATURE °F.						RELATIVE HUMIDITY %		
Dry Bulb			Wet Bulb					
Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.
93	98	95.8	77.5	79	78.2	39	54	45.7

Incl. #2

TABLE 11

COMPARISON OF THE SWEAT LOSS, RECTAL TEMPERATURE AND PULSE RATE OF CREWS OF THE TOTALLY PROTECTED, POSITIVE PRESSURE VENTILATED TANK (T23) WITH AND WITHOUT ADDITIONAL CIRCULATION OF THE AIR OF THE TURRET

Position	SWEAT LOSS (gr/hr.)		FINAL RECTAL TEMP. (°F.)		FINAL PULSE RATE (beats/min.)	
	T23 No fan	T23 Fan	T23 No fan	T23 Fan	T23 No fan	T23 Fan
Commander	386	355	100.0	99.2	72	64
Gunner	280	284	99.7	99.1	84	68
Loader	574	404	99.6	99.6	76	72
Bog	266	332	99.6	99.6	68	60
Driver	390	341	99.6	99.2	84	92
Average	379	343	99.7	99.3	76.8	71.2

WEATHER DATA

During Four (4) Hours of Test

Day of Test	AIR TEMPERATURE (°F.)						RELATIVE HUMIDITY (%)		
	Dry Bulb			Wet Bulb					
	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.
31	89.5	95.5	92.6	78	80	78.7	46.5	63	54.7
32	88	96	92.3	75	76.5	75.8	39	56	47

CHART I

DAILY MAXIMUM AND MINIMUM DRY AND WET BULB TEMPERATURES & RELATIVE HUMIDITY OF AMBIENT AIR AT TIME OF DAY WHEN TESTS WERE RUN

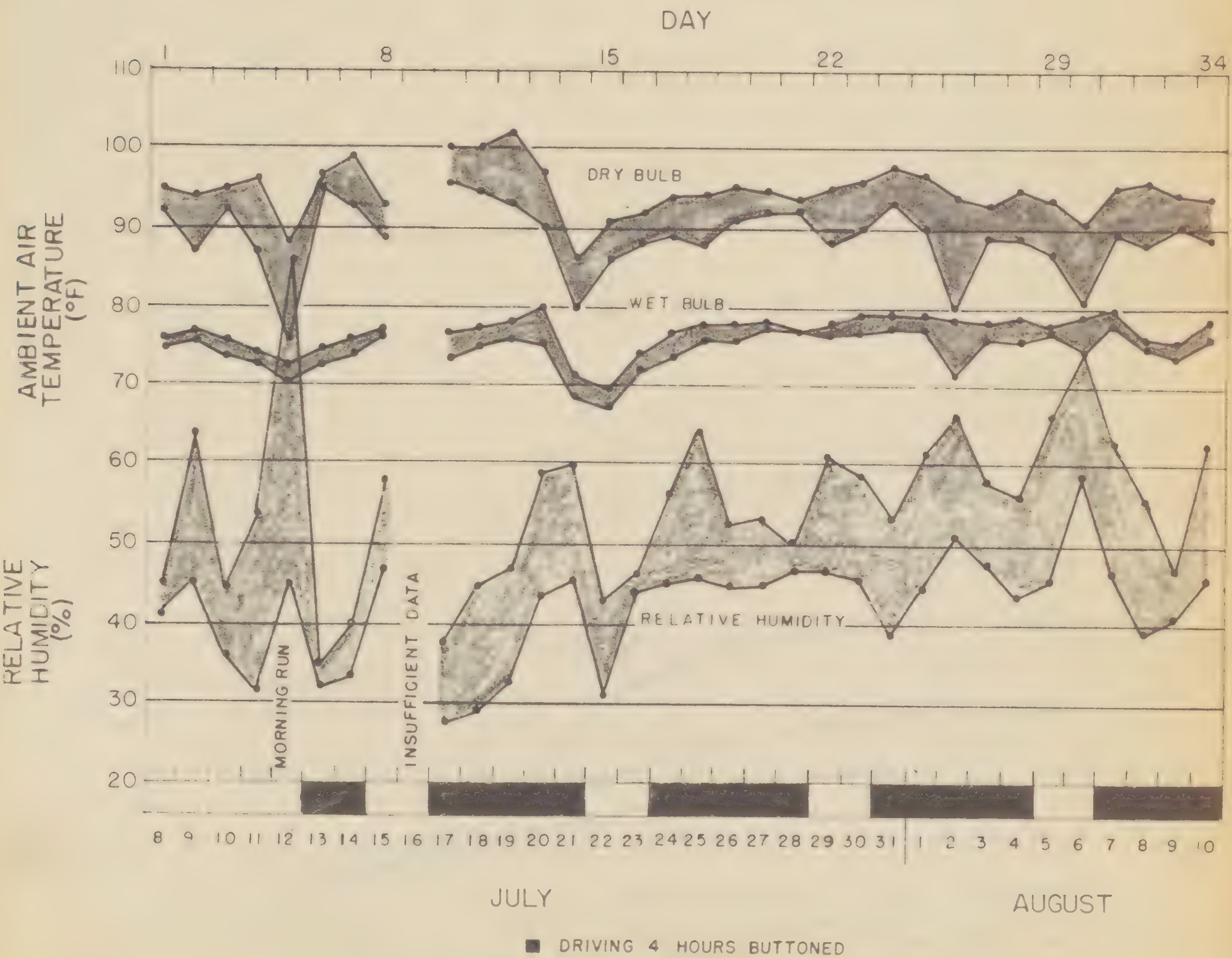


CHART 2

RELATIONSHIP OF THE HULL AND AIR TEMPERATURES OF A STANDARD M4A3 TANK TO THE EXTERNAL AIR TEMPERATURE DURING 4 HOURS OF BUTTONED OPERATION

(FAST RUN)

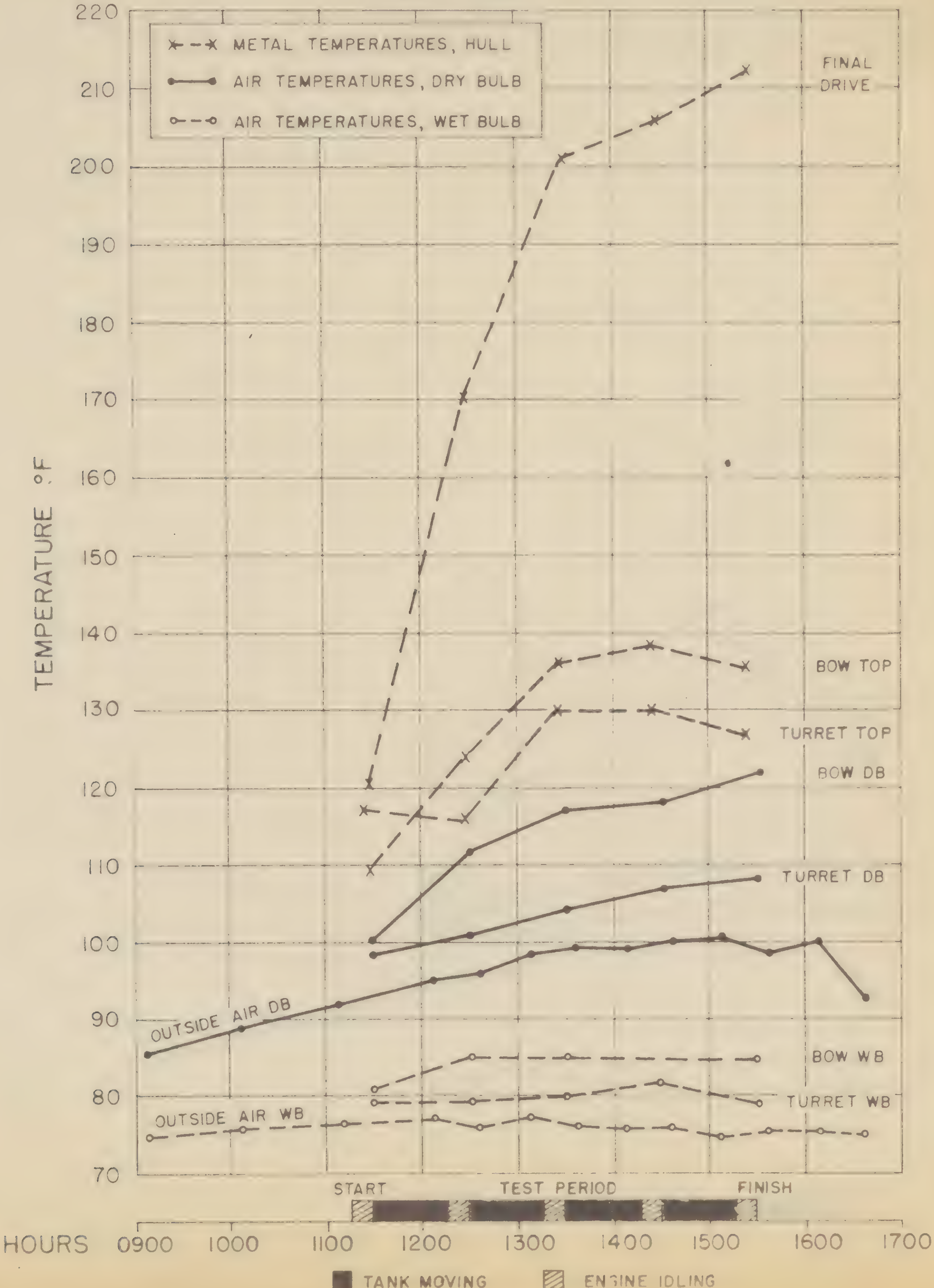
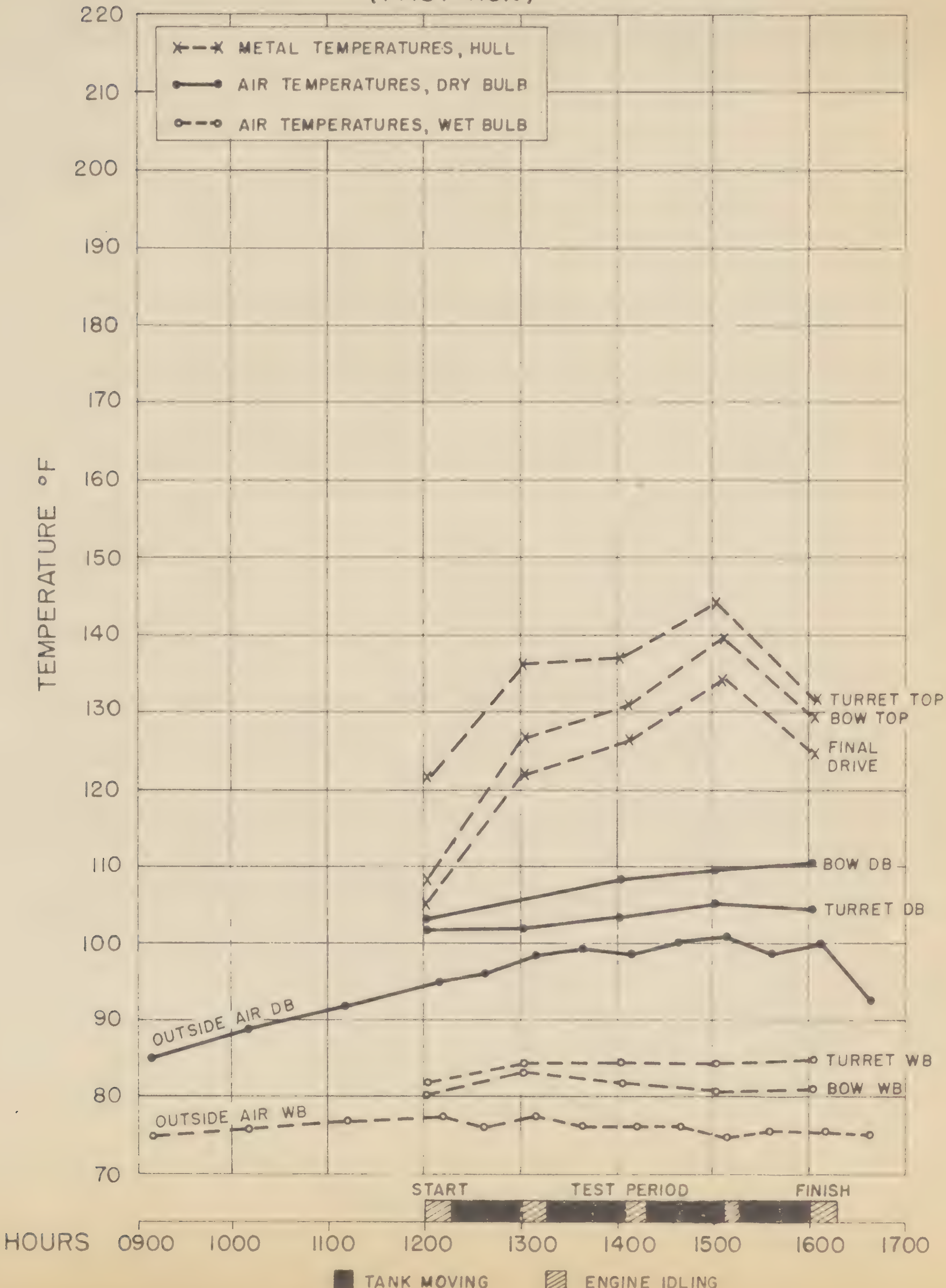


CHART 2

CHART 3

RELATIONSHIP OF THE HULL AND AIR TEMPERATURES OF TANK (T23) TO THE EXTERNAL AIR TEMPERATURE DURING 4 HOURS OF BUTTONED OPERATION

(FAST RUN)



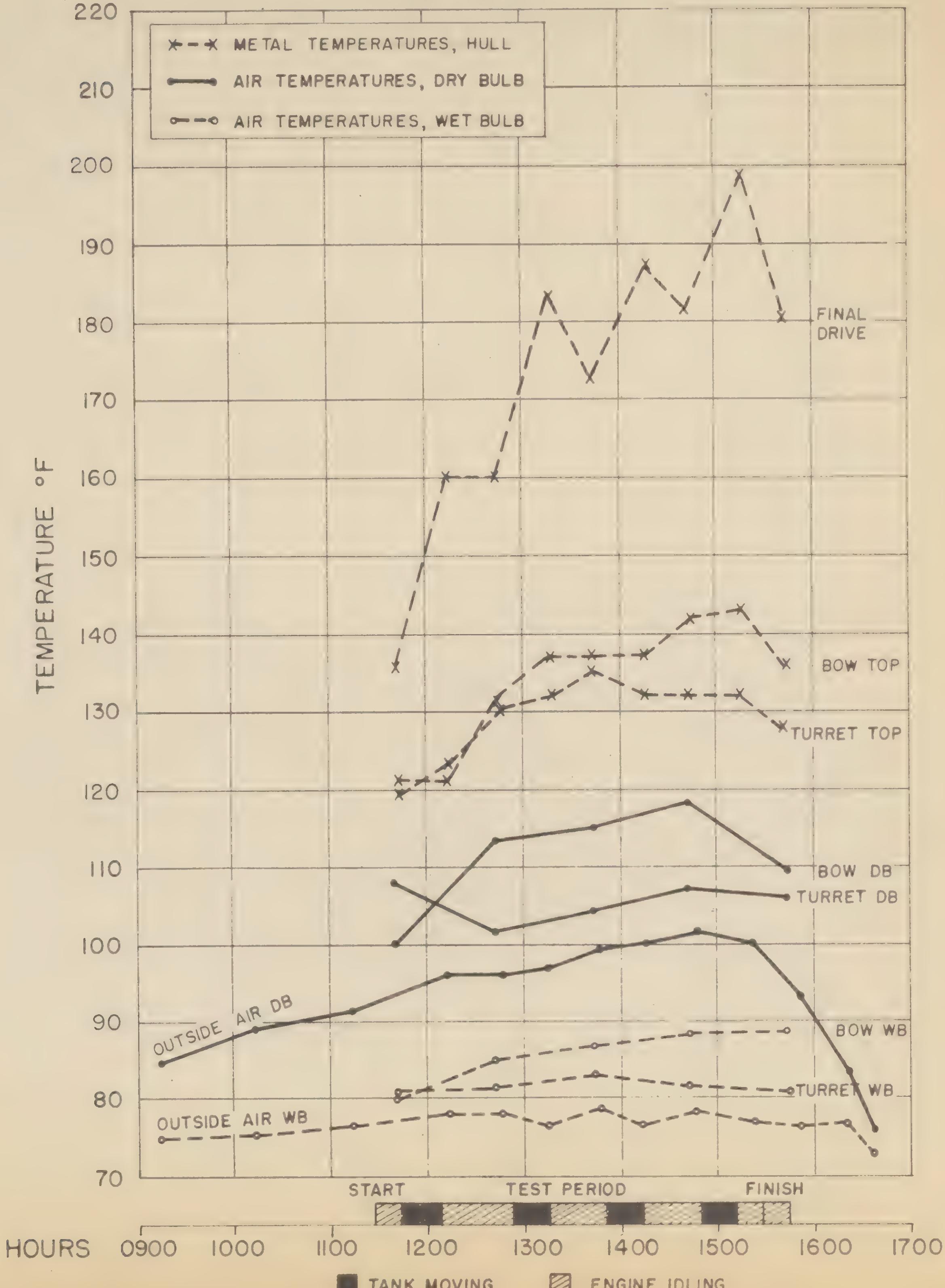
Incl. #3

CHART 3

CHART 4

RELATIONSHIP OF THE HULL AND AIR TEMPERATURES OF A STANDARD M4A3 TANK TO THE EXTERNAL AIR TEMPERATURE DURING 4 HOURS OF BUTTONED OPERATION

(SLOW RUN)



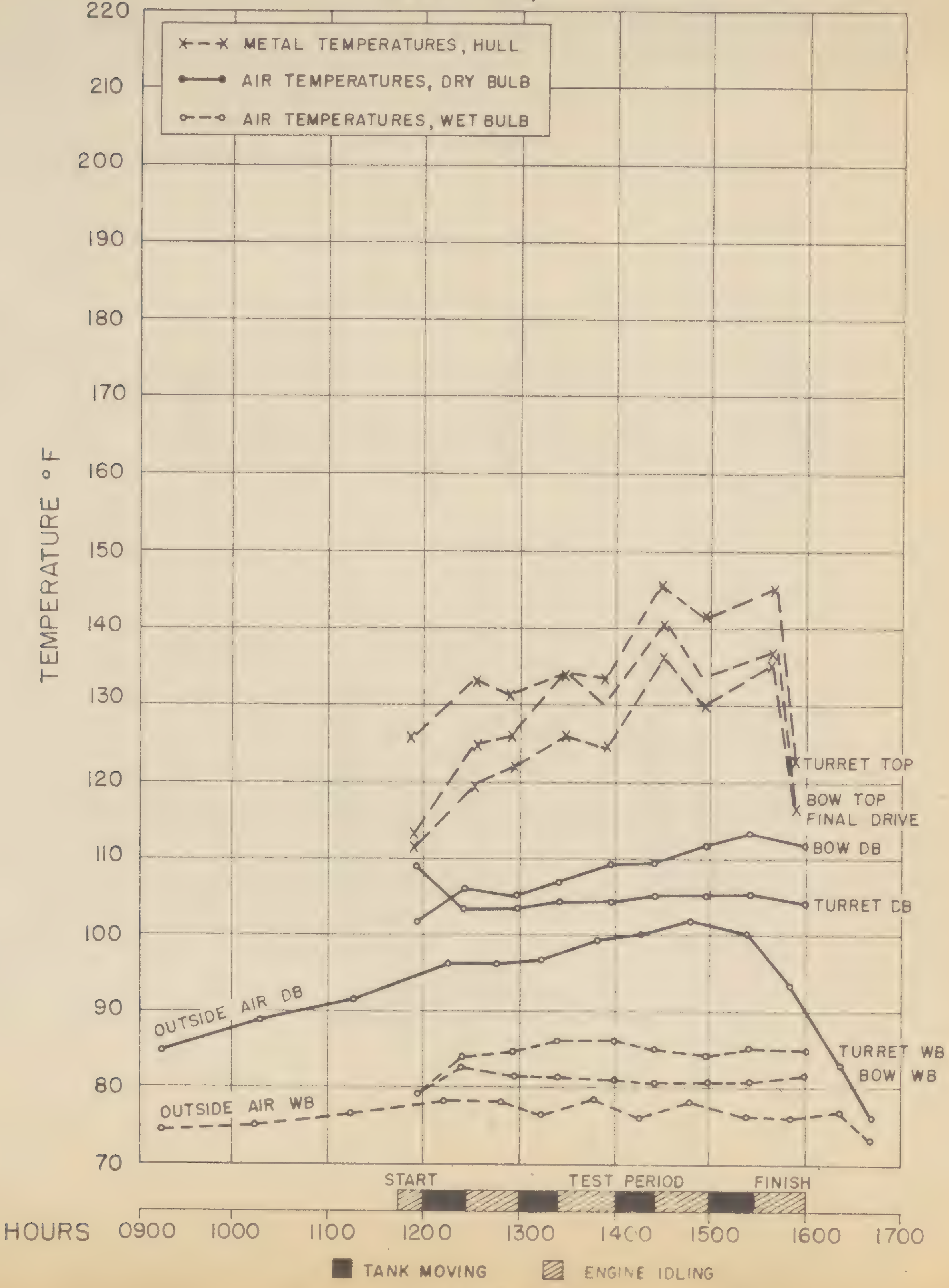
Incl. #3

CHART 4

CHART 5

RELATIONSHIP OF THE HULL AND AIR TEMPERATURES OF TANK (T 23) TO THE EXTERNAL AIR TEMPERATURE DURING 4 HOURS OF BUTTONED OPERATION

(SLOW RUN)

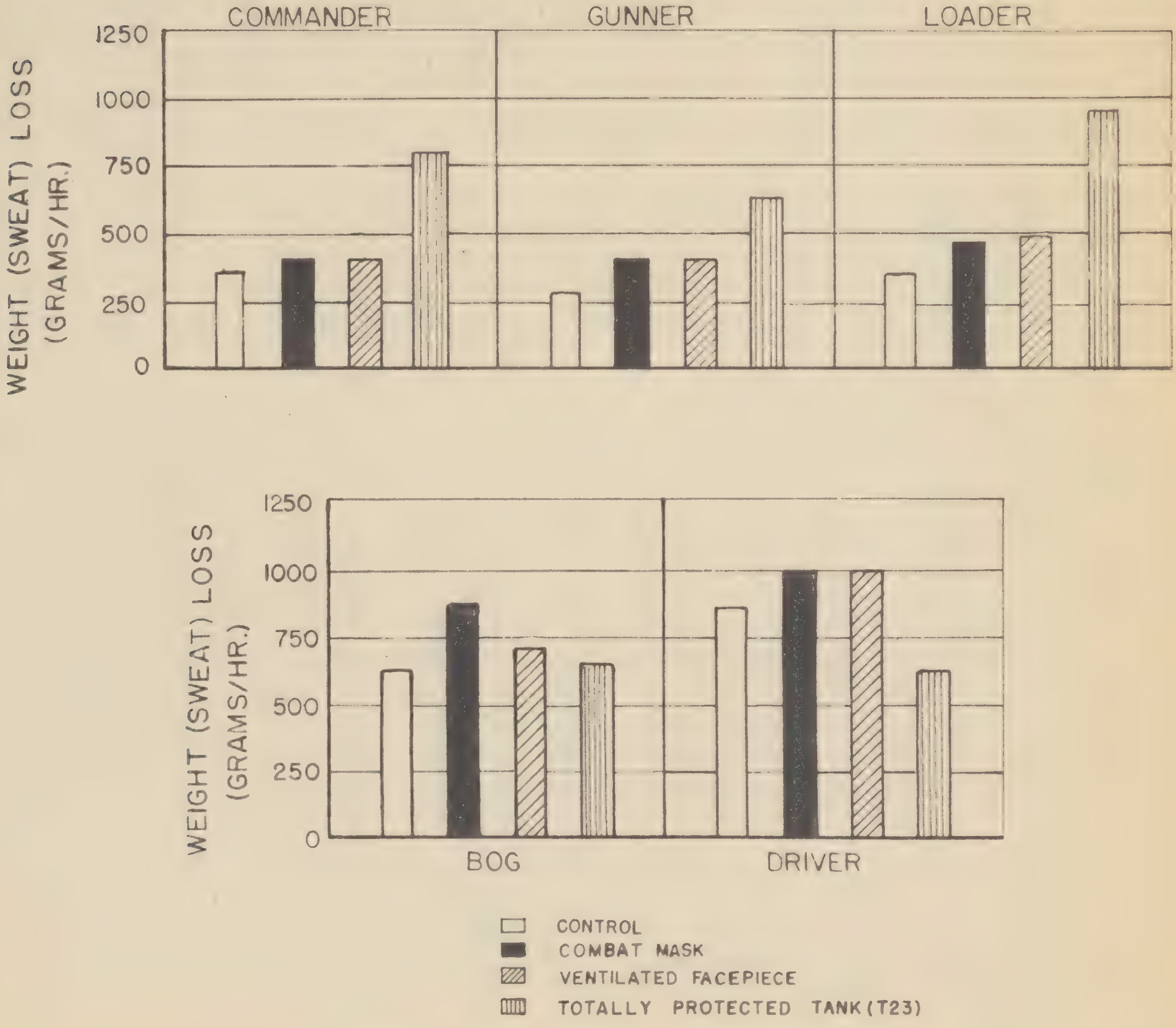


Incl. #3

CHART 5

CHART 6

WEIGHT (SWEAT) LOST PER HOUR BY TANK CREW MEMBERS EQUIPPED WITH VARIOUS METHODS FOR PROTECTION AGAINST CHEMICAL WARFARE AGENTS



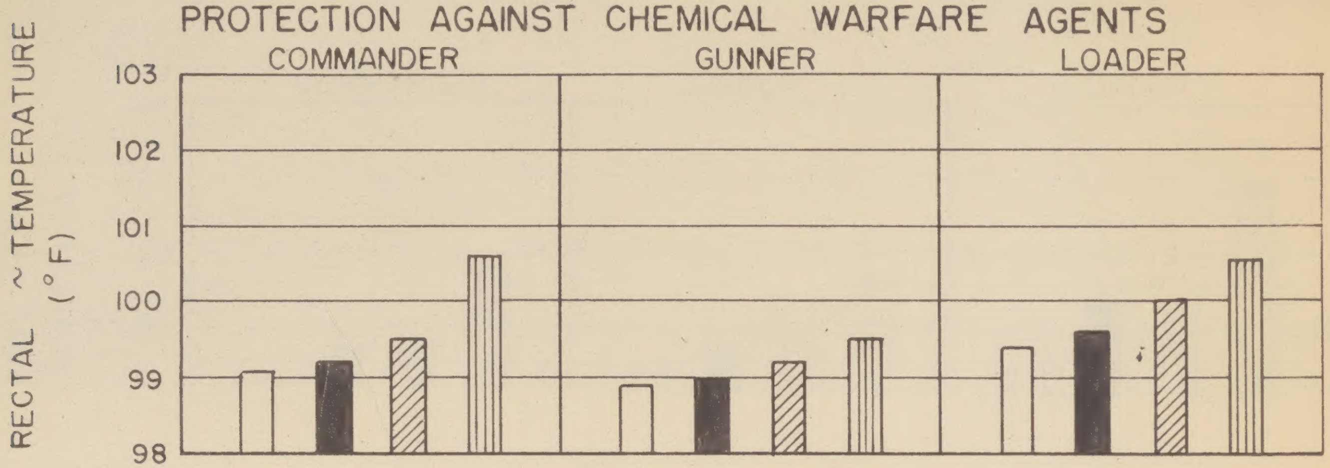
(EACH SYMBOL OF EACH LOCATION = AVERAGE OF 3 MEN)

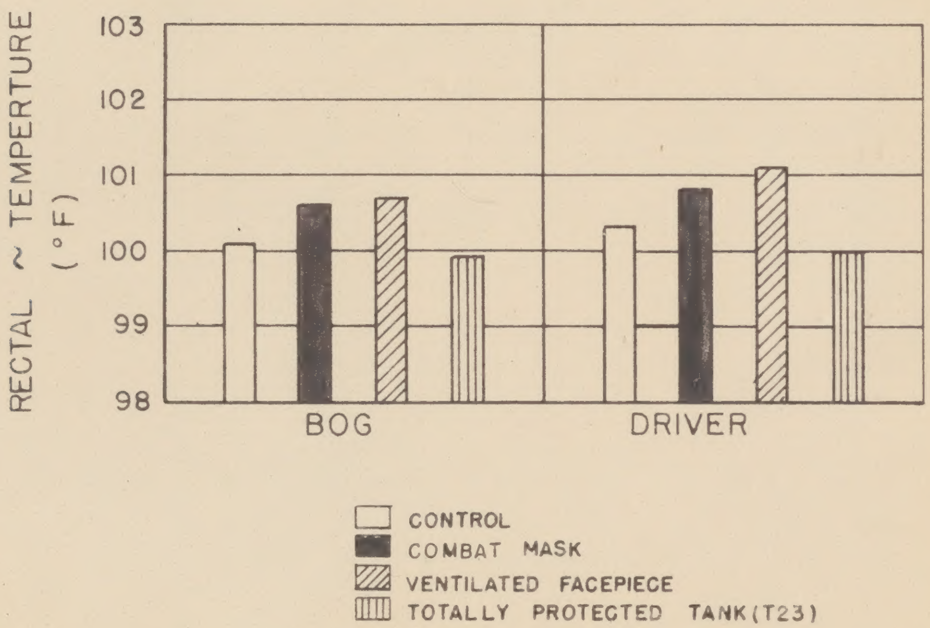
Incl. #3

CHART 6

CHART 7

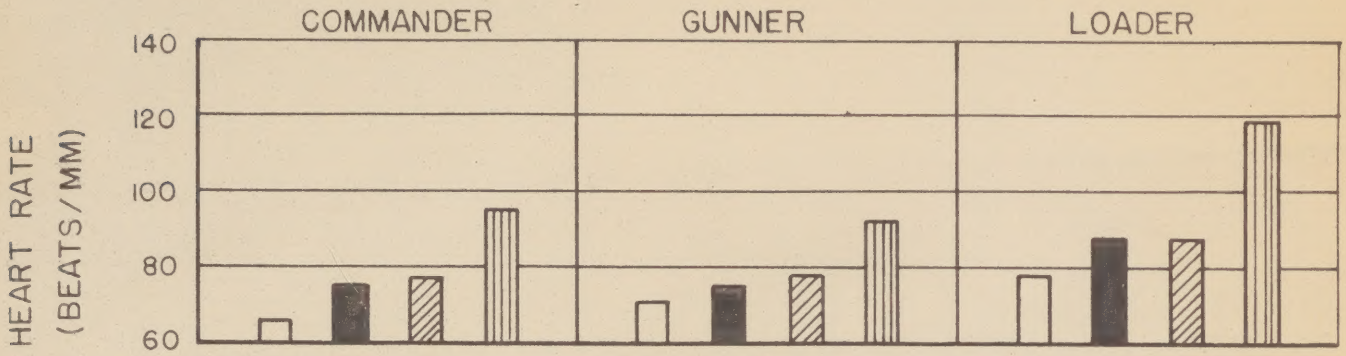
RECTAL TEMPERATURE AT THE END OF 4 HOURS OF BUTTONED OPERATION IN TANK CREWS EQUIPPED WITH VARIOUS METHODS FOR PROTECTION AGAINST CHEMICAL WARFARE AGENTS

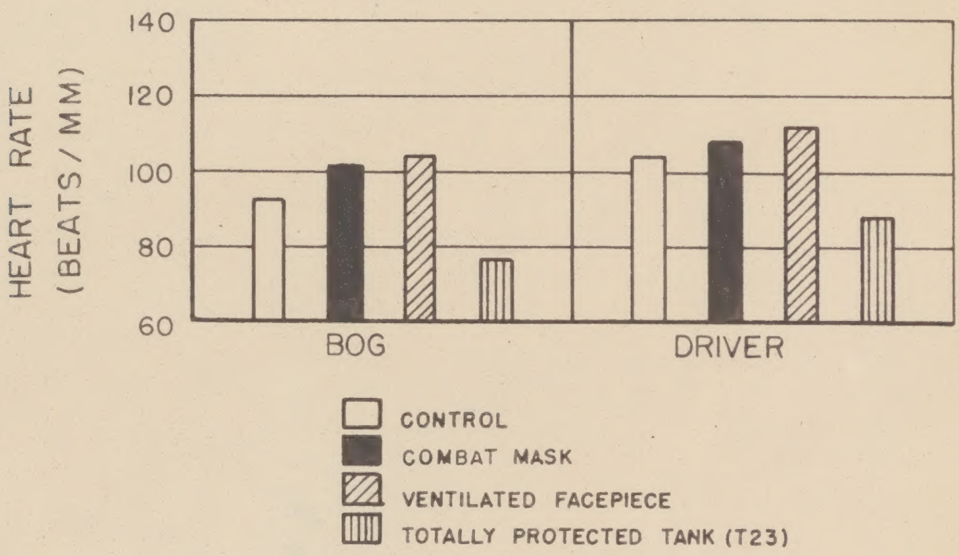




(EACH SYMBOL OF EACH LOCATION = AVERAGE OF 3 MEN)

HEART RATE AT THE END OF 4 HOURS OF BUTTONED OPERATION IN TANK CREWS EQUIPPED WITH VARIOUS METHODS FOR PROTECTION AGAINST CHEMICAL WARFARE





(EACH SYMBOL OF EACH LOCATION = AVERAGE OF 3 MEN)

11